substrate cell designs. Superstrate cells usually incorporate a textured, TCO coating on the transparent substrate (usually glass). There are many technologies for producing TCO layers from varying materials (typically SnO_2 or ZnO for a-Si-based cells) and with varying texture and electrical properties. The semiconductor layers are then deposited onto the textured TCO. Plasma deposition of the p-layer onto a textured TCO can lead to difficulties: the oxide layer may be chemically "reduced," and achieving ideal properties for a thin p-layer could be difficult. Finally, the back reflector deposited on top of the semiconductor layers is often a two-layer structure: a thin TCO layer, followed by the reflective metal (typically Ag – for best reflectivity – or Al – for improved yield in production).

In substrate cells, the semiconductor layers are actually deposited onto the back-reflector, which is again a two-layer structure starting with a textured silver or aluminum metallization and then a textured TCO [143]. Following deposition of the semiconductor layers, a top TCO layer is applied.

12.4.6 Cells under Solar Illumination

In the previous few sections, we have discussed the components of a-Si:H *pin* solar cell design. For monochromatic light and for a given intrinsic layer thickness, we have described the effects of the absorption length and the intensity, the effects of the slow (and dispersive) hole transport and the relatively rapid electron transport, and the use of back reflectors and texturing to enhance the photocurrents realized from weakly absorbed light. In this section we use essentially the same model for these effects as we have in previous sections, but extend it to a cell's operation under polychromatic, solar illumination. In addition, when we changed the band gap, we left all other model parameters unchanged. This discussion continues in the following sections on multijunction (and multi–band gap) cells.

In Figure 12.20 we present calculations of the PV parameters J_{SC}, FF, V_{OC}, and solar conversion efficiency for *pin* solar cells of varying thickness and electrical band gap. First note the increase in short-circuit current J_{SC} as the band gap is reduced (at constant thickness); this effect is due to the increase in optical absorption coefficients in the infrared as the band gap is reduced (cf. Figure 12.10). Also note that the short-circuit current depends only weakly upon thickness beyond the first 100 nm of thickness, which accounts for a substantial fraction of the total absorption. The decline of V_{OC} with band gap of course duplicates the experimental trend of Figure 12.19. Interestingly, V_{OC} remains essentially independent of thickness under solar illumination, despite the "front loading" of the photon absorption. On the other hand, the fill factors under solar illumination are substantially larger than that for uniform illumination. Finally, the differing trends of V_{OC} and of J_{SC} with band gap conspire to determine a maximum efficiency of about 11.3% for a cell with a band gap of 1.45 eV and a thickness greater than about 300 nm. While the neglect of deep levels is too idealized for these calculations to precisely describe the efficiencies, the calculations nonetheless indicate the principal trends of changing the band gap. They also suggest the strategy that has been used to achieve higher efficiencies. In particular, the effects of a decline in V_{OC} with band gap in single-junction cell can be avoided by building multijunction solar cells, as we describe in the next section.